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Silent Inspector Implementation Procedures for Hopper and Pipeline Dredges

PURPOSE: This technical note (TN) documents the process for implementing the U. S. Army Corps of Engineers' Silent Inspector (SI) system, an automated dredge contract monitoring system.

BACKGROUND: The role of the Corps has shifted from dredge owner/operator to that of contract inspector and administrator since the 1976 reduction of the government-owned hydraulic dredge fleet. More recently, reduced Federal inspector manpower and increased numbers of dredging contracts have significantly impaired the Corps' ability to perform adequate dredging contractor oversight (Rosati and Welp 1999). Automated systems have been developed to assist dredging inspectors in project management and to provide more accurate monitoring of dredge activities for both hopper and pipeline dredges.

The Dredging Operations Environmental Research (DOER) Program SI work unit was established in 1998 to develop standardized, automated monitoring SI systems for Corps-wide hopper and pipeline dredging activities. The objectives of the SI systems are to assist dredge inspectors, dredging project and contract managers in monitoring dredging position and dredge production status, and to provide trustworthy facts for dispute resolution. A more detailed discussion of these objectives is provided in Rosati (2000). Other research from the SI work unit includes documentation of Corps monitoring experiences with contractor pipeline dredges (Rosati and Welp 1999).

Previously, the SI work unit has identified Corps and contractor monitoring processes, and SI data and equipment needs for development of contractor SI specifications. The SI system has been developed and used onboard Corps and contractor dredges. However, the Corps and contractors must follow several major steps (including both administrative and technical work) to achieve a viable, working SI system for contractor monitoring purposes. This TN focuses on describing the SI system implementation process on contractor hopper and pipeline dredges.

SI SYSTEM OVERVIEW: The hopper and pipeline dredge SI systems integrate various automated systems to record digital dredging and disposal activities for both government-owned and contract dredges. Both SI systems collect and record measurements from shipboard sensors, calculate the dredging activities, and display this information using standard reports and graphical displays.

The SI systems have three major computer components: the Dredge Specific System (DSS), the Ship Server and the Shore System. These components and their functions are described as follows:

- Most dredging contractors use computer-based systems for positioning and perhaps control of their dredge. These systems comprise the SI DSS. The DSS collects various dredge sensor

data, and formats and displays these data to the dredge crew to provide quality control of the dredging project.

- The DSS sends data in near real-time to the Ship Server (in a standard format), which is another computer on the dredge loaded with Corps SI software. The Ship Server then performs tasks that include automated review of data for quality assurance, data archival, report generation, and graphical displays of data.

- The Shore System provides the same functionality as the Ship Server, but has greater data storage and data reporting capabilities. Data (which may include daily reports) are taken from dredges either by wireless data link or magnetic media and are archived on the Shore System.

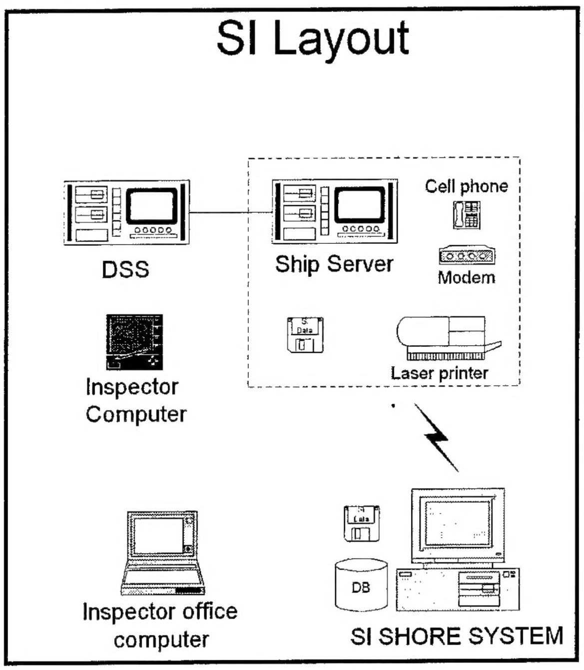

Figure 1. SI system layout

Figure 1 is an illustration of the SI system components and configuration. Inspector computers are also shown in Figure 1. These inspector computers are additional onboard computers such as a laptop personal computer or hand-held computing device with SI software that can connect to the Ship Server or Shore System. They are an optional part of the system that adds operational flexibility by allowing multiple user access to the SI system throughout the dredge. Dredging contractors are not required to supply inspector computers (unless otherwise noted in the specifications), and existing Corps computers may be used as an inspector computer. Shore-based SI users will typically use their existing desktop computer to run the freely available SI software and connect with the SI database to view SI data.

The DSS and all shipboard sensors are the property of the contractor, who is required to maintain them. The contractor purchases the Ship Server computer hardware for the Corps, and the Corps installs SI software on the Ship Server computer. The Shore System consists of Corps-supplied hardware and software. The Corps SI software on the Ship Server is similar for both hopper and pipeline SI systems. Both hopper and pipeline dredge SI systems monitor dredge position and dredge state, and report and manage these data for Corps dredging contracts. However, each system collects data and computes measurements specific to each dredging type. The data collected by each SI system are listed in Table 1. Additionally, the hopper dredge SI system computes Tons Dry Solids (TDS).

Table 1
Data Collected for Hopper and Pipeline Dredge SI Systems

Hopper Dredge	Pipeline Dredge
Horizontal position	Cutterhead horizontal position and depth
Hopper status (open/closed)	Slurry velocity and density
Tide level	Tide level or river stage
Ship speed and heading	Dredge heading
Material recovery and min. pump effort	N/A
Draft, displacement	N/A
Hopper ullage and volume	N/A
Draghead depth	N/A

Both hopper and pipeline dredge SI systems have been field proven through demonstration projects. Recently, the SI system was implemented on two hopper dredges: Bean Stuyvesant's *Stuyvesant* in May 2000, and the B+B Dredging Company *Columbus* (later renamed the *Columbia*) in January 1998. Also in 1999, pipeline SI system implementation was tested on the Corps dredge, the *William A. Thompson*.

IMPLEMENTATION PROCESS: The SI implementation process consists of developing and defining the interactive Corps and dredging contractor relationship so that management decisions can be obtained from a common basis of factual information. The SI System implementation process is one of continuous improvement and is described in several major steps.

- *Step 1.* Corps development of SI contract specifications and submittal of those specifications to the contractor (via the contracting process)
- *Step 2.* Contractor development of a Dredge Plant Instrumentation Plan (DPIP), and submittal of the DPIP to the Corps
- *Step 3.* Corps approval of the DPIP
- *Step 4.* Contractor provides an operational SI system
- *Step 5.* Corps installs SI software
- *Step 6.* Corps inspects SI system
- *Step 7.* Continued quality assurance testing and contractor quality control throughout dredging operations (Corps and contractor)
- *Step 8.* Incorporate lessons learned and technology improvements into the contract specifications and repeat *Steps 1-7* for subsequent projects

SI Contract Specifications. The SI contract specifications define and describe the Corps and dredging contractor relationship with regard to SI system equipment, data collection, data quality control, and data quality assurance. A Process Action Team (PAT) composed of dredging contractors and the Corps developed an SI contract specification guide. Dredging

instrumentation subcontractors and consulting engineers also reviewed the specifications and provided technical guidance. Detailed information about the SI contract specification guide can be obtained from SI points of contact provided at the end of this document.

Because dredging contract requirements vary between Corps Districts, each District can tailor the SI contract specifications to meet its specific dredging needs. In addition, these specifications may differ from contract to contract within a District if different types of dredging are required. However, one of the main purposes of the SI system is to standardize the monitoring requirements so that a contractor's dredge may work for various Corps Districts with a minimum amount of SI system modifications to meet disparate monitoring requirements. The SI specifications are included in dredging contract bid packages distributed by the District.

In general, the SI contract specifications for hopper and pipeline dredges include details related to the following topics:

- DPIP requirements
- Contractor-provided sensor and data requirements
  - Type, number, and locations
  - Quality control criteria
  - Minimum data performance requirements
  - Data reporting and format
  - Reference datum(s)
- Contractor-provided computer equipment
- Data-reporting interface requirements
- Quality assurance test descriptions and requirements (predredging and during dredging)
- Table of contractor-specific deliverables
- DPIP submittal schedule
- Data format examples and related definitions

One of the most important elements of the SI specifications is the format in which the SI data are reported. The SI system has extended the National Marine Electronics Association (NMEA) format commonly used by many instruments aboard dredges (NMEA 1998). The purpose of this extended format is to provide a standardized data interface between the DSS and Ship Server for all SI system measurements. The general data format for the SI system interface is given as follows:

```
$Paaa,LABEL,x.x---------------------------,*hh<CR><LF>
```

where

`$P` = Proprietary sentence identifier

`aaa` = Three-letter manufacturer's mnemonic code

`LABEL` = SI sentence label
`x.x` = Sentence comma delimited data
`*hh` = Checksum
`<CR><LF>` = End of sentence

Rules were also developed for the SI system data format. Each contractor will be assigned a three-letter identifier to be placed in the manufacturer's mnemonic code. The sentence label identifies the sentence corresponding to a predefined sentence format. Data that are not required or unknown may be represented by a null field („) following the NMEA convention, and data sentences that are not relevant to a particular project and do not contain required data may be omitted.

The SI system data format is to be used for data reporting of all dredge information, including that for dredge navigation, tide elevation, sensor output, and dredge production. Table 2 describes some of the data sentences used to transfer data. Required data values for a particular contract are given in the specific deliverables section of the SI specifications. The SI specifications include the detailed data sentence formats and examples.

Table 2
SI Data Sentences

Label	Data Description
DPOS	Horizontal positioning
DHCS	Heading, course, speed
BDEN	Hopper (bin) density-related data
TIDE	Tide
DRAG	Hopper dredge dragarm-specific data
PROD	Pipeline dredge production
DSTAT	Hopper dredge status reporting
DPUMP	Pipeline dredge pump
BPUMP	Pipeline dredge booster pump (optional)
SPPOS	Pipeline dredge spud horizontal position (optional)
CHPOS	Pipeline cutterhead position
RST	Riverstage
CRPM	Pipeline cutterhead RPM (optional)

Dredge Plant Instrumentation Plan (DPIP). The SI specifications require the contractor to submit a DPIP (Step 2). The DPIP documents the contractor's SI monitoring equipment and operations, and supplies extensive information about the dredge that is needed by the Corps to fulfill its data quality assurance role.

More specifically, the DPIP provides details to the Corps about the dredge and equipment, data collection and procedures, and quality control (QC) measures. The DPIP must show how the contractor will conduct the following tasks:

- Gather sensor data
- Compute required data elements
- Perform quality control on those data
- Calibrate and repair sensors/data reporting equipment when they fail
- Distribute the sensor data and computed dredge-specific data to the Corps via a standard interface

Information about dredge dimensions and sensor layouts are needed in the DPIP so that the Corps can adequately perform a dredge inspection. The SI specifications require that a certified marine surveyor or architect certify most dredge dimensions.

Additionally, descriptive information about the dredge and SI system equipment (sensors and computers) must be included in the DPIP. Table 3 lists the different information types required in the DPIP for hopper and pipeline dredges.

Corps DPIP Approval. Once the contractor submits the DPIP, the Corps reviews the DPIP within a specified time period (denoted in the SI contract specifications) and gives written approval. This approval is valid for a certain period of time (one year for example) and can be transferred between Districts at their discretion. Once written, the contractor should update the DPIP when sensor upgrades or dredge plant modifications occur.

Contractor-operational SI System. Once the Corps approves the DPIP, the dredging contractors should have their DSS reporting the required data to the Ship Server within the time period stipulated in the SI specifications.

Corps SI System Inspection. After the system is made operational, the Corps will schedule and conduct an onboard SI system inspection to determine if the contractor's DSS is reporting data according to specifications. Onsite inspection assures the District that the contractor's instrumentation system (sensors, data acquisition equipment, and software) meets the equipment and performance requirements given in the SI specifications. The objective of this physical inspection is to provide the District with confidence that the dredge data meets the specifications at the time of inspection. The inspection results are documented in a letter report with a copy furnished to the dredge contractor.

The dredge inspection includes Corps observation of installed SI system equipment, QA checks, and data results. QA checks are an important aspect associated with SI system implementation. These checks verify the accuracy and/or consistency of sensor and system performance. Pre-dredging QA checks provide a basis of comparison for spot checks of the dredge's data during dredging operations. The QA tests for hopper and pipeline dredges are described as follows. Welp and Rosati (2000) describe the hopper dredge QA tests in greater detail.

Table 3
Required DPIP Information for Hopper and Pipeline Dredges

Information Types	Hopper Dredge	Pipeline Dredge
Dredge computation procedures	Vessel displacement	Cutterhead position
	Hopper material volume	
	Ullage table	
	Material recovery	Cutterhead depth
	Pumping water	Dredge production
	Minimum pumping effort	
Dredge dimensions	Dragpipe lengths and inside pipe diameter	Cutterhead and inside pipe diameter
	Offset distance from DGPS antenna to center line of each draghead	Offset distance from DGPS antenna to the center line of the cutterhead
	Distances from fore and aft draft sensors: • Horizontal and vertical distances from the keel and between each draft sensor • Vertical distances to the hopper level sensors • Distances from aft draft sensor to aft perpendicular and midship section • Distances of fore draft sensor to fore perpendicular and midship section	Slurry density and slurry velocity sensor locations
	Draft and hopper sensor offsets	
Dimensioned drawings	Overall dredge	Overall dredge, including hull and decks, sensor locations, cutter basket diameter, distance between spuds, and suction ladder length(s)
	Hopper, including hopper length, depth, and width, with hopper level sensors referenced to overall dimensions	
	Typical mid-ship cross section	
Quality control methods	Sensor calibration checks	Sensor calibration checks
	Data quality checks	Data quality checks
	Quality assurance tests and checks	Quality assurance tests and checks
Contractor-provided computer hardware and software	Brand name	Brand name
	Specifications	Specifications
Data reporting interface	Proposed revisions	Proposed revisions
Sensors[1]	Brand name	Brand name
	Description of sensor operation and accuracy according to manufacturer specifications	Description of sensor operation and accuracy according to manufacturer specifications
	Certificates of calibration and/or manufacturer certificates of compliance for draft, slurry density and velocity, hopper level, water depth, and draghead depth sensors	Certificates of calibration and/or manufacturer certificates of compliance for slurry density and velocity, and cutterhead depth sensors

[1] Note: Sensor manuals do not constitute a submittal of sensor descriptions and calibration information.

- **Water test (hopper dredges).** The objective of the water test is to assure data consistency for TDS calculation by comparing the SI system-measured specific gravity of water to an average specific gravity of water determined from hopper water sample analyses. The clean hopper is filled with water to check operation and data reporting of ullage and draft sensors, and respective data collection hardware and software. The sensor-measured specific gravity of the water is calculated and compared to the average specific gravity of water samples taken from various locations in the hopper that are measured with a temperature-compensated hand-held refractometer. Because of the absence of solid particles, the ideal calculated value of TDS should equal zero with water (of a known density) in the hopper.

- **Water test (pipeline dredges).** Water is pumped through the pipeline to check operation and accuracy of slurry velocity and slurry density.

- **Trim-trim test (hopper dredges).** The trim-trim test also checks operation and data reporting of ullage and draft sensors. Two independent inclination (trim-trim) angles are calculated from the ullage sensor measurements and difference in displacement by the draft sensors. If the respective sensors are functioning correctly, then subtraction of these angles should (ideally) equal zero.

- **Relative water level test (hopper dredges).** The objective of the relative water level test is to check the accuracy of ullage and draft sensor-measured values of the same water plane for hopper dredges with bottom dump doors. The bottom dump doors are opened to allow the water level surrounding the dredge to equalize with the water level in the hopper. When compared, ullage and draft measurements should equal the fixed distance between the draft and hopper level sensors.

- **Hopper ullage/level check (hopper dredges).** The objective of the hopper ullage/level check is to verify the accuracy of the ullage/level sensor measurements. Hopper level is measured with a weighted tape measure at stations located by the ullage sensors. Simultaneously, ullage sensor measurements are observed, recorded, and compared with the tape measurements.

- **Draghead/cutterhead depth check (hopper/pipeline dredges).** The objective of this check is to verify the accuracy of draghead/cutterhead depths recorded from depth measurement sensors. Draghead/cutterhead depths are measured manually and compared with sensor values.

- **Draft/displacement check (hopper dredges).** This test verifies the accuracy of forward and aft displacement sensors. In relatively calm waters (to minimize wave-induced measurement error), external forward and aft drafts (both starboard and port) are observed, recorded, and then compared to draft sensor measurements.

Corps SI Software Installation. The Corps will install the SI system software on the dredge and verify it to be operational on or about the time of the dredge inspection. The SI software can be installed on the Shore System at any time during the contracting process.

Continued QA Testing and Instrument Calibration. The QA tests and checks previously described must be conducted before dredging begins. However, continued tests and checks of SI equipment operation must also be conducted throughout dredging operations to ensure that the contractor's instrumentation system (sensors, data acquisition equipment, and software) maintains the equipment and performance requirements given in the SI specifications and established during the dredging inspection.

The SI specifications should include information about the frequency for each QA test to be conducted during dredging operations. Continued tests, checks, and calibrations will be required on a regular basis during contract execution, after instrumentation equipment and/or software repair or modifications, and at arbitrary times based on Corps discretion. These tests are documented and stored in the SI Shore System database.

SI IMPLEMENTATION GUIDANCE

Implementation Time Line. The time line for SI system implementation is also an important element in the implementation process. An adequate time line for implementation ensures that both the Corps and the dredging contractor can meet all steps in the process. The time that this process takes will vary from District to District because of different experience levels for the Corps and contractor personnel involved, and depends on the length of each dredging operation. In 1999, the U.S. Army Engineer District, Mobile, implemented the SI system and provided a schedule in the SI specifications for continuing implementation (Table 4).

Table 4
Mobile District Implementation Schedule

Implementation Task	Time Requirement
Preconstruction conference	Scheduled after contract is awarded
Contractor DPIP submittal	Within 60 days after the Corps Notice to Proceed
Corps DPIP review and approval	Within 15 days after contractor DPIP submittal
Corps inspection and approval; Operational SI system	Within 60 days after the Corps Notice to Proceed
Continued QA tests and checks	Scheduled during dredging operations to meet SI specifications

It is expected that future implementations of the SI system process will require less time than the example schedule provided in Table 4. Most hopper and larger pipeline dredges already have required instrumentation already onboard, which will speed up the steps of DPIP development and making the system operational. In addition, once the Corps and dredging contractors gain experience with SI implementation, the process will become more defined and the time needed to set up an SI contract will be reduced. The initial contract incorporating the SI specifications for a District or contractor should be of sufficient duration to allow the contractor the time needed to meet the SI specification requirements.

Noncompliance with SI Specifications. The Corps' enforcement of noncompliance with the SI contract specifications is similar to enforcement of other parts of the dredging contract,

and depends on the actions and judgement of each Corps District. Districts and their sponsors need the dredging work accomplished and greatly prefer some sort of penalty short of disrupting a contractor's work. For example, the Mobile District uses the following clause in their hopper dredge rental contracts.

> *If the system is not operational within 30 days of the Notice to Proceed, or if the system becomes inoperable for a period of time greater than allowed in the specification, the hourly rate of pay for the dredge for 100% time will be reduced to 95% of the original bid price until the system is fully operational.*

Proprietary Information and Security. In consultation with the SI PAT team, the detailed dredge data are considered proprietary as well as the contractor submittals. In contrast, summarized data derived from detailed dredge data (i.e., ENG Forms 27 and 4267 time distributions) are not considered proprietary.

SUMMARY: The SI system implementation process for hopper and pipeline dredges integrates into the dredging contracting process. This process defines the interactive relationship between the Corps and the dredging contractor with regard to dredge monitoring and helps the Corps to perform its quality assurance role. In addition, the detailed dredging data can allow for new ways to interact with the contractor.

POINTS OF CONTACT: For additional information on the Silent Inspector System, contact the principal investigators, Mr. James Rosati (601-634-2022, *James.Rosati@erdc.usace.army.mil*) and Mr. Timothy Welp (601-634-2070, *Timothy.L.Welp@erdc.usace.army.mil*) or the DOER Program Manager, Dr. Robert M. Engler (601-634-3624, *Robert.M.Engler@erdc.usace.army.mil*). This technical note should be cited as follows:

> Rosati, J., III, and Prickett, T. L. (2001). "Silent Inspector implementation procedures for hopper and pipeline dredges," *DOER Technical Notes Collection* (ERDC TN-DOER-I6), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/eldots/doer*

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